CUSTOMS
LABORATORY
BULLETIN

Volume 8 Number 2
October 1996

THE MEASUREMENT OF SOFT SPRINGBACK AND IMPACT ABSORPTION PROPERTIES OF ERGONOMIC POLYURETHANE FOAMS

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INTRODUCTION

The Canadian government had been requested by industry to provide special tariff treatment for ergonomic grades of polyurethane (PU) foams which are commonly used for comfort cushioning in wheelchairs and other medical devices. The following tests were developed to provide simple and efficient methods to differentiate this type of foam from other PU foams.

The unique compression-deflection behaviour of ergonomic foams results not only from their chemical composition, but most importantly from their open cell structure that allows the free movement of air inside the foam when it is deflected **[1]**. The resulting properties include low rebound, good energy absorption (typically in excess of 90%) and gradual but complete recovery from intermittent loadings.

Standard methods for testing of moulded urethane foams are compiled under comprehensive ASTM method D 3574 **[2]**. Indentation load deflection (ILD) Tests B_1 and B_2 are often used to measure cushioning capabilities, while "Ball Rebound" Test H is used for testing resilience or energy absorption properties. None of the standard tests however measures simple dynamic properties such as the rate of recovery from deflection. For example, Test D of the above mentioned ASTM method (a "Constant Deflection Compression Set Test") only measures the degree of recovery, but not the speed of recovery.

In the present work, a new test has been developed to measure the recovery time of deflected foams and a "Ball Rebound" Test H of ASTM D 3574 has been adopted with some modifications.

EXPERIMENTAL

Test 1

CONSTANT DEFLECTION TEST - SPECIFIED SET (Supplemental Method for ASTM D 3574) [2]

1. Summary of Method

The method measures the time necessary for the deflected foam specimen to recover from 25% to 75% of its original thickness.

2. Apparatus

- *Compression Device*, consists of a flat plate equipped with a handle which is used on a flat surface, e.g., laboratory table;

- the required deflection is achieved by the use of *spacers*;

- the time of recovery is measured using a *stopwatch* having a LCD display and an accuracy of 1/100 of a second;

- the 75% set is established using a *ruler* with the smallest division of 1 millimetre; and

- the recovery time is determined using a *videocamera* to record the recovery and a suitable *viewing system* enabling the play back of the recovery process in slow motion.

3. Test Specimens

The test specimens must have parallel top and bottom surfaces and minimum dimensions of 50 mm by 50 mm and 38 to 51 mm thick.

4. Procedure

- the entire test procedure is conducted at 23 ± 2°C and

50 ± 2% relative humidity and is continuously monitored and recorded by the use of videocamera;

- the specimen is deflected and held at 25% of its original thickness for approximately 1 minute;

- the compression plate is removed quickly;

- the time (t_0) at which the compression plate is removed and the time (t_{75}) at which the flat top of the specimen reaches 75% of its original height are determined during the play-back of the recovery process. Some samples will deform during recovery. This situation may occur when the foam has very small cells. In this instance the thickness of the specimen at its centre should be monitored.

- if the recovery time measurements are repeated on the same specimen, a minimum interval time of 5 minutes should be allowed between each trial.

5. Calculations

The recovery time t_r necessary for the deflected specimen to recover from 25% to 75% of its original thickness is calculated, as follows:

$$t_r = t_{75} - t_0$$

where:

t_r indicates recovery time expressed in seconds;

t_{75} indicates time at which recovery reaches 75% of original height; and

t_0 indicates time at which recovery begins.

Calculate the mean of at least three trials. If any value deviates more than 20% from this mean, make two additional trials and calculate the mean for all five trials.

6. Report

Report the calculated recovery time in seconds.

Test 2

RESILIENCE (BALL REBOUND) TEST (Modified ASTM D 3574 Test H)[2]

1. Summary of Method

The test consists of dropping a steel ball on a foam specimen and noting the height of the rebound (bounce).

2. Apparatus

- a *ball rebound tester* consists of a clear, vertical plastic tube, such as acrylic, with 38 mm inside diameter;

- a *steel ball* of a diameter of 16 mm and a weight of 16.3 g is released into the plastic tube without rotation. The height of the drop is 500 mm above the specimen surface (the top of the ball is positioned 516 mm above the surface of the foam. "Zero" rebound is equal to the diameter of the ball);

- a *ruler* with the smallest division of 1 mm is positioned beside the tube; and

- a *videocamera* and *viewing system* enabling play back in slow motion is used to allow good precision in determining the amount of rebound.

3. Test Specimens

The test specimens must have parallel top and bottom surfaces and minimum dimensions of 50 mm by 50 mm and at least 38 mm thick.

4. Procedure

- the entire test procedure is conducted at 23 ± 2°C and 50 ± 2% relative humidity and is continuously monitored and recorded by the use of videocamera;

- the specimen is positioned at the base of the tube. The tube and the ruler are adjusted so that "zero rebound" is 16 mm above the surface of the foam specimen;
- the ball is released from the centre top of the tube;
- the height of the rebound is determined during the play-back of the rebound process. If the ball strikes the tube on the drop or rebound, the value obtained is invalid.

5. Calculations

The rebound is expressed as a percentage of the release height, as follows:

$$\text{Rebound (\%)} = (h_b/500\ \text{mm}) \times 100$$

where:

h_b indicates height of rebound (bounce) expressed in millimetres; and

500 mm indicates the height of ball drop

Calculate the mean of at least three rebound values. If any value deviates more than 20% from this mean, make two additional drops and calculate the mean for all five drops.

6. Report

Report the calculated Ball Rebound Resilience Value of the sample as a percentage.

RESULTS AND DISCUSSION

The average recovery times and the average rebounds were measured using Test 1 and Test 2, respectively. The temperature of 23 ± 2°C and the relative humidity of 50 ± 2% were selected for both tests to meet conditions reported in the ASTM method D 3574 **[2]**. Various grades of PU foams have been tested and the results are included in Table 1. Samples with designations A through E and F through H, respectively, represent two different sets of ergonomic PU foams obtained from two independent manufacturing sources. An "ordinary" polyurethane household sponge (sample I), with an open cell structure has also been tested for comparison.

Within the first series (samples A through E), the ball rebound values were found to decrease from approximately 14% to approximately 8% as the recovery times increased from 1.1 second to 2.6 seconds. The rebound was also found to be inversely proportional to the sample's firmness within this series. Although the values of relative firmness were unknown for the second set (samples F through H), a similar rebound/recovery pattern was observed. Generally, the higher the ball rebound, the shorter the time for the sample to recover from deflection. Recovery times fell within a relatively narrow range for all tested specimens of ergonomic foams, essentially, within 0.5 - 3.0 seconds. The rebound, on the other hand showed a greater diversity. For example, sample H exhibited remarkable dampening properties with a barely measurable rebound at 0.2%, while in case of sample A, the ball rebounded to a sizable 14%.

The "ordinary" polyurethane household sponge behaved quite differently. Not only did it have a clearly distinguishable ball rebound of 26%, but its recovery time from deflection was more than an order of a magnitude shorter than any tested ergonomic foam.

CONCLUSION

The soft springback property of ergonomic polyurethane foam was effectively expressed in terms of recovery time necessary for the deflected foam specimen to recover from 25% to 75% of its original thickness. The high impact absorption, another unique property of ergonomic PU foam, was determined using a modified ASTM ball rebound test **[2]**. For both properties, video equipment with slow motion playback capabilities was necessary to make the measurements. The soft springback and the high impact absorption properties were useful in distinguishing between ergonomic grades of PU foams and other PU foams.

ACKNOWLEDGEMENT

The author would like to thank Dr. Pavel Neudorfl from the R & D Division at the Revenue Canada Laboratory and Scientific Services Directorate for providing and assisting in the operation of the video equipment used in this work.

REFERENCES

1. Meinecke, E.A. and Clark, R.C., "Mechanic Properties of Polymeric Foams", Technomic, 1973

2. Standard Methods of Testing for Flexible Cellular Materials - Slab, Bonded, and Moulded Urethane Foams, ASTM D 3574-77, p. 471.

Table 1

Experimental Results for Average Recovery Time in Test 1 and Average Rebound in Test 2

Sample[a]	Recovery time [s]	Rebound [%]
A soft (0.73 PSI)	1.28	14.5
B medium-soft (0.82 PSI)	1.10	10.4
C[b] medium (0.92 PSI)	1.3	8.9
D medium-firm (0.99 PSI)	1.60	7.0
E firm (1.20 PSI)	2.63	8.5
F[c]	0.65	0.93
G[c]	1.08	0.40
H[c]	1.13	0.20
I[b,d]	0.05	26.0

a numbers in parentheses indicate support pressure in pounds per square inch (relate to the firmness of the foam) as claimed by the manufacturer

b 38 mm thick specimen

c ergonomic foam of undisclosed firmness and support pressure

d an open cell polyurethane household sponge